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FINAL REPORT
ADVANCED TILT-TOP LIGHT TABLE
ADVANCED FILM-VIEWING LIGHT TABLES

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SUMMARY

This report presents the results of a preliminary design study for determining design configuration for three Advanced Light Tables. Design drawings are submitted and in conjunction with text, fully describe the proposed equipments. The development objectives have been met in all major particulars. In the few instances where the proposed design is at variance with the objectives, reasons are given to support a recommendation for changes in the development objectives.

SECTION I

Project [redacted] Table

I-1 Recommended Design Concepts

General Description - Drawings [redacted] define the external configuration and the film drive gearing configuration. Except for electrical power required for illumination, the table is entirely mechanical. The design submitted herein is:

32 inches long (not including spools)
16 inches wide (not including crank handles)
9 inches high (not including spools)
50 pounds in weight (estimated)

Drawing [redacted] shows the recommended control layout for the [redacted] Light Table. Please note that the drawing [redacted] (Film Drive and Film Drive Schematic) is common to all three light table designs discussed in this document. The control layouts differ in some respects, but the film drive functional performance is identical for Model [redacted] light tables. Differences in control layout are occasioned by the differing dimensions and somewhat different utilization of [redacted] tables.

Discussion - The [redacted] light table will be constructed on a cast aluminum base. The casting will be ribbed and stiffened where necessary to provide a rugged, durable unit. The base mounts a readily available 300:1 ratio, double-worm gearbox. The worm-drive provides a self-locking feature which prevents any possibility of the elevated light box falling down when the gearbox knob is released. The cast base also provides a mounting surface for the general illumination transformer underneath a sheet-metal enclosure. The transformer mounts on the base rather than

[redacted]

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In the light table itself for two reasons;

a) To reduce the weight which has to be lifted by the gearbox, and

b) To obtain a more advantageous center-of-gravity by using the weight of the transformer to counterbalance light table weight.

Pivot Plate - The pivot plate is carried on trunnions attached to the double-ended gearbox output shaft and in turn carries the light box assembly. A carefully selected pivot location provides a center for the rotation of the light box with respect to the pivot plate in such a way as to cause the light box to maintain proper geometric alignment with the base regardless of which of its two positions it is in. The pivot point will be a hollow shaft and will allow the necessary wires from the base and transformer to enter the light box at the center of rotation. Rotation of the light box will be limited by stops so that "wrap-up" of wires will not be possible. A quick-release pivot-lock in one corner of the pivot plate will fix the light box in either of its two positions.

Light Box - The light box structure will be a combination of end castings and heavy, formed, structural connecting members. The light box will contain an [redacted] cold-cathode grid, capable of providing an average illumination level of 1900 foot-lamberts with a uniformity of better than 10% and controllable from 100% to approximately 12% of light level. Actual tests made in October 1964, of an 11 x 20 inch grid did not meet the uniformity requirement but the light levels at the center were 300 to 400 foot-lamberts higher than required, and it is believed that these can be sprayed down to even out the average range. Maximum film temperature measured was 108 degrees F. Some variation from the above should be anticipated from one grid to another.

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The light box also contains two adjustable shades whose controls are shown on drawing These are capable of being independently positioned and independently locked by rotating the positioning knob. STAT STAT

Tilt Mechanism - Considerably more flexibility has been provided in this recommended design than was required by the development objective. Tilt, in either of two axes, is possible from zero degrees (light table horizontal) to a full 90 degrees (light table vertical). A full 90 degrees of tilt will require approximately 75 turns of the gearbox handwheel with an applied force of approximately 2 1/2 pounds at the worst condition; namely, a full 500 foot spool on the upper end of the table, the table starting from a horizontal position and being elevated for use on the long axis. Spring counterbalancing will be provided at the tilt axis so that maximum safe loads are never exceeded in the gearbox. For protection of the gearbox, in the event of excessive externally applied forces in the elevated position, a brace bar is provided. This is an extensible, automatically locking assembly which may be manually placed into a socket on the pivot plate and extended until the brace bar takes load. A finger release on the brace bar permits the bar to telescope and be stored in a position permitting lowering of the tilted light box.

Spool Loading - Three film size spools are accommodated in accord with the development objective. The recommended loading method for a single 9 1/2 inch spool is as follows:

a) Center support is hinged away.

b) One headstock (either side) is cocked outboard against a spring and into a detent position.

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c) In the detent position, an ample clearance exists (3/8 to 1/2 inch) between the two spool support pins.

d) Film spool is placed into position between spool support pins and engaged with headstock pin.

e) Pressure is manually exerted with film spool against headstock support pin until the "trigger" holding the headstock in "cocked" position releases.

f) Headstock is moved forward by spring, closing the gap between spool support pins.

Loading of smaller spools is identical to the description above except that the hinged center support is used and the process is repeated twice, once with each headstock. Release of the spool is a reverse process of manually forcing the spool against the headstock until it moves backwards into the "cocked" position.

<u>Center-of-Gravity</u> - Estimates of weight, calculations and mock-up studies indicate that worst-case center-of-gravity would be well within four inches from the edge of the base. This will provide a stable configuration which will not easily upset with normal use and handling.

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<u>Film Transport</u> - All the development objectives have been met in addition to the alternate configuration of proposal, which permits all film drive functions to be accomplished from a single handwheel. The following film handling functions are possible:

a) Emulsion, up or down, independently at either spool.

b) One to one, or one to three film drive speed.

[redacted]

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c) Two films driven independently, one from each of two handwheels. In this mode, the films can be moved: one at a time; both in the same direction, or each in a different direction.

d) Two films driven together from one handwheel. In this mode, the films can be moved: both in the same direction; both in opposite directions.

e) Film tensioning by separate tensioning control. The use of separate tensioning control was chosen because of the need to use the Model [redacted] Light Table from the long axis. Linear movement of the film drive handwheel ("in" and "out") when seated in the "normal" position, i.e., facing across the short axis, is possible because the hand and arm are relatively powerful in fore and aft directions. When seated at the long axis, however, this fore and aft movement of the handwheel would be rotated ninety degrees and become a "side to side" (transverse) movement of the handwheel. In this axis the arm is relatively weak and this mode of doing work is not recommended by human factors handbooks. The film tensioning control is placed in a convenient position and can be easily reached when using the table on either long or short axes. Film cannot be driven when the tensioning control is in "on" position due to a mechanical interlock.

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Three possible modes of film drive are possible. These are as follows (see Drawing [redacted]:

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a) Single 9 1/2 inch film.

b) Two films with independent drive.

c) Two films with "coupled" drive.

Positioning of controls for each of the above modes is as follows:

a) SET EMULSION CONTROLS (4 PLACES) IN SAME MODE.
SET DRIVE COUPLER IN "INDEPENDENT" POSITION.
SET BOTH SPEED SELECTORS IN SAME RANGE, EITHER "HIGH" OR "LOW". This will enable operator to drive 9 1/2 inch film in either direction with any handwheel, or to drive in one direction with one handwheel, and in reverse direction with another handwheel.

b) SET EMULSION CONTROLS (4 PLACES) IN DESIRED POSITIONS - THESE MAY BE INDEPENDENT ON FRONT OR REAR FILMS, AND MAY EVEN REWIND ONE FILM FROM A SPOOL EMULSION "UP" TO THE OTHER SPOOL EMULSION "DOWN".
SET DRIVE COUPLER IN "INDEPENDENT" POSITION.
SET BOTH SPEED SELECTORS IN SAME OR DIFFERENT RANGES AS DESIRED. This will enable operator to drive two films independently from two handwheels with complete flexibility to advance one only, move two in same or opposite directions.

c) SET EMULSION CONTROLS (4 PLACES) IN DESIRED POSITIONS AS IN (b) ABOVE.
SET DRIVE COUPLER IN EITHER "SAME" OR "OPPOSITE" DIRECTIONS.
SET SPEED SELECTORS IN SAME SPEED RANGE.
With these settings, all films will be controlled from any of three handwheels. To move only one film while in the "coupled" mode, set speed selector of the film which is to remain stationary in "NEUTRAL" position.

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I-2 . Other Design Approaches Considered

Tilting Mechanisms

Slide arrangements and ball and socket arrangements were considered and rejected, in the first instance because of greater complexity and resulting increased cost and in the second because of the difficulty in maintaining adjustment of preload and friction on a ball surface.

Belt drives were considered for film transport and rejected in favor of direct drive or selective use of chain because of greater reliability and fewer adjustments of the direct drive design.

Tensioning of film by a fore and aft motion of the film drive handwheels was rejected in favor of a separate but interlocked tensioning control. For a discussion of the reasons, see the paragraphs relating to film tensioning in Section I-1.

A film transport design based on the use of gear differentials was considered and rejected because of the large number of gears involved, and the resulting higher loads and higher costs.

Other means for tilting the light box were considered. Various arrangements of pneumatic or hydraulic cylinders in combination with linkages, cams or scissor jacks were studied. Some had merit in terms of high-load carrying capacity, but were rejected for reasons of possible leakage and for the undesirable increase in complexity.

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Electromechanical clutches were studied for use in making gear changes with the possibility that all film drive modes could be controlled from one multi-position switch. The directness and simplicity of this scheme from an operator's point of view, was attractive. The use of electrical clutching, however, was not selected, even though it appeared to have a small cost advantage, because the Development Objective appeared to direct the design in a wholly mechanical direction.

I-3 Recommended Changes in Development Objective

Since all the Development Objectives have been met, no strong recommendations for changes are proposed. Some discussion, however, is in order regarding the questions of film drive speeds, film drive modes and film drive loads.

For purposes of keeping costs to a minimum, the gearing design has been based on the use of relatively inexpensive brass gears; perhaps even molded nylon gears in certain locations, and the use of sleeve bushings at all possible points rather than ball bearings. Many design compromises were made with relatively low cost production design. Some of these compromises undoubtedly increase the frictional losses and it is [redacted] opinion that the manual film driving loads in a 1:3 speed range may well be considered excessive even when driving only one film on each handwheel.

If the foregoing is true, there is no doubt that the loads will be excessive when the "coupled" mode is used, i.e., one handwheel driving two films. Some considerable doubt exists in our minds as to the value, in this Model [redacted] design, of the "coupled" mode. Since two handwheels are readily and comfortably available to the operator regardless of which table position is being used, it would not appear necessary or desirable to perform all film drive functions from one wheel at the expense of additional cost, complexity and greater expenditure of manual effort.

If our assumptions are correct, (there is no practical way to analytically determine film driving loads) then it would be reasonable to assume that operators will not use the "coupled" mode if the required effort is excessive. A tentative recommendation is, therefore, made that reconsideration be given to the actual necessity for a gear drive ratio as high as 1:3, and to the desirability of a "coupled" mode. Additional attention is given to these matters in paragraph I-4 "Design Options".

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I-4 Design Options

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Drive Speed - In the discussion of paragraph I-3, some doubt was expressed as to the acceptability of a drive speed ratio as high as 1:3. It is entirely possible to vary this ratio in a partially completed prototype equipment without change of gear-centers. The degree of possible change would be in downward increments chosen, as possible, from other combinations of gears whose pitch diameters add to the same center to center distance, chosen for the 1:3 ratio. It should be noted, however, that such new ratio combinations are not infinitely variable and might work out to relatively large ratio increments such as, for example, 1:2.4 or 1:2.2.

Assisted Drive - A third option directed toward solving the possible problem of high manual film drive loads is discussed here. This approach would incorporate a torque motor, probably of an A.C. hysteresis type, in an appropriate point in the gearing. The direction of motor drive would be controlled by a torque sensitive switch on the handwheels so that the first motion of a handwheel would close switches and determine the direction of motor drive. Motor torque would be selected below that needed to move film so that the torque provided by the motor would be used only to overcome the major portion of the friction load, with the operator furnishing only the force required to overcome dynamic loads. Please note, that this option has not been studied under this contract, nor was such an arrangement contemplated in [redacted] STAT
[redacted] estimating of prototype design and fabrication costs. STAT

[redacted]

SECTION II

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Projects [redacted] Tables

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II-1 Recommended Design Concepts

General Description

Drawings [redacted] STAT

[redacted] show the external configuration of the Models [redacted] STAT design, an alternate configuration of measuring equipment for a STAT production version of Model 605 and a full size view of a measuring micrometer proposed for use in one of the alternate configurations.

The advanced film viewing light table design recommended herein is:

60 inches long (not including spools)
21 inches wide (not including crank handles)
7 inches high (not including spools)
300 pounds (estimated)

Certain common design features have been incorporated in Models [redacted] These are specifically in STAT the areas of general illumination and in film drive mechanisms. Since these were discussed fully in Section I of this report, the complete discussion will not be repeated, and differences only will be covered.

[redacted]

No separate discussion is provided for Models [redacted] inasmuch as the differences are matters of deletion, in accordance with the Development Objective. For the purposes of this document, the more complicated Model [redacted] is described, it being understood that Model [redacted] is identical in all respects except for features not required. STAT STAT STAT STAT

Discussion - Basic Structure - The recommended Model [redacted] design is constructed upon a base casting of stabilized aluminum. The casting will be stiffened, webbed, flanged and/or ribbed to provide the stability and rigidity necessary for a highly accurate measuring machine. Where very accurate and/or wearing surfaces are required, the aluminum casting will be equipped with machined or ground steel, suitable for the specific application. In order to achieve the greatest possible degree of rigidity in the basic structure, a unique method of tracking hi-intensity light sources has been designed. This method does away with the need for a long slot at the back of the basic structure through which, normally, a moving light-source arm would travel. STAT

Carriages - In conformity with the Development Objective, a two axis (X and Y) carriage arrangement has been included in the design. Many ways of providing the necessary motions were studied (see paragraph II-2 for details) including three and four carriage arrangements. The recommended design uses only two motions, and has the virtue of simplicity, lowest cost and highest accuracy. Also studied were many ways of supporting and guiding the X and Y carriages. The recommended configuration represents the most desirable combination of compromises. It consists of one guiding pair of Vee ways on one edge of the X axis and another pair on one edge of the Y axis. Between the Vees is a ground and polished bronze rod. While not the lowest friction design, it is the only arrangement which will provide the required accuracies. The Vees will be made from [redacted] (or equivalent) material and consists of SAE52100 ball bearing steel welded to softer steel. The wearing surfaces are heat treated to 64-66 STAT [redacted] C hardness and ground and polished to required accuracies. STAT Chrome flash will be used for corrosion protection. STAT

X and Y carriage travels are determined by the single-edge Vee accuracy. The opposite end of each carriage is freely supported on a hardened, ground flat way, fastened, in turn, to the basic aluminum structure. Both X and Y carriages are themselves single piece aluminum castings; stiffened and ribbed.

Microscope Adapters - Drawing [redacted] shows adapter STAT designs for the three microscopes to be used with the light table. STAT The [redacted] microscope actually requires two individual mounts for the two axes of possible viewing inasmuch as the microscope itself cannot be rotated on its own axis.

High Intensity Light Sources - As discussed in [redacted] STAT [redacted] proposal, a unique approach has been taken to the problem of providing two individually adjustable tracking light sources. STAT In order to eliminate the usual long carriage extension arm and rear casting slot customarily employed with tracking high-intensity sources, it has been decided to use magnetic means of causing a low-friction, lightweight illumination assembly underneath the film plane to track a small but powerful magnet attached to the traveling X-Y carriages. The two individual illumination assemblies underneath the film plane are essentially free bodies. Light from a fixed lamp is brought to the free body through a one-eighth inch diameter fiber optic light pipe, long enough to allow each high-intensity source to reach anywhere the microscope can travel. The upper tracking magnets are cylindrical and are carried on adjustable arms so the distance and orientation between magnets can be adjusted to the microscope in use and locked into position. Once the upper magnets are locked in place, they track with the microscope in both X and Y. It will be necessary, initially to use a separate magnet for capturing the free body illumination source and to move it from its last current position

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into the general area of the microscope at which point it may easily be captured and held by moving the X-Y carriages until the microscope magnet locks-on. Once locked on, the two illumination sources will track with the microscope. If it is desired to remove the high intensity sources from the locked-on position, the supplementary magnet, which will be much more powerful, can be used to "capture" the light source to move it out of the viewing area and to release it.

The source of high-intensity light is a single lamp, 30 watts, and located in a cartridge assembly. The condenser system consists of two aspheric lenses. Provisions are made for slip-in filters either for color correction or for neutral density filters which may be desired when viewing at low magnifications. Individual intensity control of each source is possible by rotating a threaded collar at each end of the cartridge assembly. This moves the end of the fiber optic light pipe out of the cone of greatest light intensity and is very effective in reducing the amount of light at the viewing surface without changing color temperature.

Studies of the optical properties of the three microscopes show that one-half inch diameter of high-intensity light will fill the aperture at 100 x magnification. Further calculations and laboratory setups have indicated that 18,000 foot-lamberts at the film plane is a more than satisfactory level when viewing film of density two.

Such levels have been achieved using the design shown. The isolation from heat sources by use of the light pipe results in negligable film heating at the highest intensity.

[redacted]

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General Illumination - The discussion on general illumination given in Section I of this report is pertinent here except that two individual cold cathode grids would be employed to cover the larger area of the Model [redacted] Light Table. A common intensity control is provided, but there are two on-off switches and two pilot lights for greater flexibility of control. 25X1

Film Loading - Film is loaded and unloaded in exactly the same fashion as described for Model [redacted] STAT

Film Transport - Model [redacted] has the same number of film drive controls as Model [redacted] and these controls perform the same functions. The only difference is in the absence of the third handwheel. A third handwheel at the right rear of the light table is virtually impossible in the case of Model [redacted] because: STAT STAT STAT

a) The X-Y carriage sweeps out an area so large that the handwheel would have to be located six or more inches out from the main structure.

b) Even if located far enough out from structure, the operator's hand will unavoidably be hitting the table upon which the Model [redacted] is resting. This would not be the case with Model [redacted] since the third handwheel is used only when the table is elevated and the operator was seated at one end. STAT STAT

The absence of the third handwheel only means that the "coupled" mode must be used when viewing from the right end of the light table. The tensioning control has been relocated in the Model [redacted] to bring it in reach of an operator viewing from the right end. STAT

Jacking Means - Simple screwjack arrangements have been provided for elevating and leveling the entire table by three STAT
inches. Using the same screwjacks it is possible to tilt the table, either on the long or short axes, to an angle of 15 degrees. Actuation of the four independent screwjacks is from the top surface of the table by a key, see drawing [redacted] STAT

Measuring - One recommended configuration and one option configuration are discussed in this report. (See paragraph II-4 for option) In accordance with the Development Objective, a micrometer of suitable accuracy and size was incorporated into the design on each measurement axis. This micrometer was a four
25X1 inch diameter [redacted] with direct reading to one micron and interpolation to one-half micron and was in accord with paragraph 4.5.3.3 of the Development Objective. When this micrometer was found to be objectionably large during a customer inspection
25X1 of the Model [redacted] mockup, a smaller version was designed and is the one shown mounted in drawing [redacted] and in full size STAT
detail in drawing [redacted] Note that a vernier has been incorporated into the smaller micrometer which would make possible a least count of one micron but not an extrapolation to one-half micron. STAT

Although not shown in drawing [redacted] the STAT
micrometers, which are mounted on sub-carriages, are actually spring captured to the main carriages in such fashion that the sub-carriages are forced to travel with the main carriages. When a measuring position is reached and the sub-carriage micrometer-locking-knob is tightened, the main carriage may be moved only through the measuring distance and only by rotation of the micrometer barrel. Measuring to the required accuracy takes place by direct reading of the two inch micrometer barrel and vernier.

II-2 Other Design Approaches Considered

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Carriage Suspension - Four different basic approaches to guiding the X and Y stages were investigated at length. These included dove-tail sections, ball-bushings on round rods, various types of preloaded slides and the use of high accuracy ball bearings in connection with the inverted Vee, in place of the round bronze rod finally selected. All of the methods studied were deemed to have lower accuracy and repeatability than could be tolerated. Several experimental setups were made to verify the conclusions with actual measurements.

Microscope Suspension - Three and four carriage configurations were studied in depth and rejected in favor of the two carriage design contained in the earlier paragraphs of this Section. Three and four carriage designs resulted in intolerable dimensional buildups, problems with overhang of the microscope (cantilevered load) and additive build-up of measuring tolerances.

High Intensity Sources - A cable drive system operating through a long slot in the rear of the main casting was studied. This approach, while feasible, required a considerable degree of complexity and other mechanical and cost compromises which made it less attractive than the one selected.

II-3 Recommended Changes in Development Objectives STAT

Except as discussed below, the Development Objectives have been met in general and in detail.

High-Intensity Light Source - Color temperature of the tungsten lamp used as a light source will be 3200 degrees K. However, some additional change in color temperature will be observed due to the use of a fiber optic light pipe, although this will be minimized by use of a relatively new glass available STAT
Nevertheless, it is apparent that the requirement for 3500 degree K (paragraph 4.1.2.5) cannot be met with a 3200 degree K light source without correcting filters. Such filters cause a substantial loss of available light and did not appear to be justifiable when viewed in a laboratory setup made especially for studying this problem. Provisions have been made in the recommended design for slip-in filters, but it is suggested that the Development Objective be modified to reflect either a minimum 30,000 foot-lambert requirement at the film plane at 3200 degree K or a 18,000 foot-lambert requirement at 3500 degree K.

Overall Length - The requirement of paragraph 4.5.2 for microscope scan to commence one-half inch from the right edge of the illuminated area causes an interference of the X carriage with a standard film spool diameter. In order to meet this requirement, the light table dimension was increased at the right end by 2 1/2 inches. The left end was also increased by an additional 2 1/2 inches in order to gain the advantage of a large X carriage "tread" as a means of increasing the measuring stability. It is, therefore, recommended that the Development Objective be altered to permit a maximum overall length of 60 inches instead of 55 inches.

<u>Micrometer Bit Size</u> - In the discussion of paragraph II-1 it was pointed out that the four inch micrometer was found to be excessively large and was, therefore, reduced in size. This reduction must be made at the expense of least count, and it is, therefore, recommended that the Development Objective be altered to reflect a least count of one micron in place of one-half micron. STAT

II-4 Options

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<u>Measuring Means</u> - At the request of the customer, a study of an alternative method for measurement was undertaken. Drawing [redacted] shows the most satisfactory configuration for a counter-vernier readout of small measurement distances. This consists of a .5mm pitch lead screw and nut assembly retained by preloaded ball bearings, to minimize backlash in the system. Attached to one end of the shaft is the handwheel (vernier), either 4 inch diameter and calibrated as per detail "A" or "B", or 2 inch diameter as per detail "C". Connected to the other end of the shaft is the counter which will read .5mm per revolution of the screw. For example - the "Y" counter reads 13.0mm and the 4 inch vernier, as represented by detail "B", reads 490. This would then represent a total measurement of 13.490mm. Since it is quite feasible to interpolate to one half a division, a least count of .0005mm or one half micron can be achieved. STAT

The above measuring means is based on the use of specially manufactured leadscrews, nuts and verniers and, therefore, was not contemplated in [redacted] estimates of prototype manufacturing costs. Considerable tooling and special setup charges would be involved and these could not be economically amortized over two prototypes. It is further recommended, therefore, that this option not be incorporated into the prototypes but left for further study in the event production quantities result from a later procurement. STAT

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